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Evaluation of interactions within a shelterbelt agroecosystem

Carl W. Mize
Iowa State University

Joseph P. Colletti
Iowa State University, colletti@iastate.edu

Richard M. Cruse
Iowa State University, rmc@iastate.edu

Mohammad Ghaffarzadeh
Iowa State University

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Evaluation of interactions within a shelterbeit agroecosystem

Abstract: *A tree shelterbeit comprised of four rows of hybrid poplars was established near Ogden, Iowa in 1992 to evaluate shelterbeit characteristics and impacts on soil water content and crop growth andyieid. Major emphasis was on testing crops of corn and soybeans. The first three years saw little effects from the shelterbeit, and data from these years will be used to develop a baseline for future measurements. In the fourth and fifth years, corn yield patterns suggested that the shelterbeit increases yields in the zone leeward from the shelterbeit. Soybeans have not shown a response to the presence of the shelterbeit.*

Principal Investigator:
Carl Mize
Forestry

Co-investigators:
J.P. Colletti
Forestry

R. Cruse
Agronomy

M. Ghaffarzadeh
Agronomy

Iowa State University

Budget
$15,150 for year one
$15,400 for year two
$15,400 for year three

Background

Shelterbelts have been an important component of cropping systems for more than 100 years. They increase crop yield by slowing surface winds and reducing evapotranspiration, which in turn increases the crop's efficient use of soil moisture. Shelterbelts have been used to decrease wind and water erosion of topsoil and reduce the movement of fugitive pesticides and fertilizer. They offer the added benefits of creating wildlife habitat, increasing populations of beneficial insects, and being aesthetically pleasing. They can also be used to generate biomass, mulch, produce hay between rows of trees, and serve as a site for manure disposal.

Sustainability of agriculture in the Midwest requires maintenance of crop yields without further degradation of soil and water resources. The resilience of crop yields in the face of climate changes will depend on skillfully managing the microclimate in the vicinity of the crops. The time and resources required to establish a sheiterbelt for these purposes demand that the impacts be known and optimized in the design process.

In the Midwest, concerns exist about the impact of shelterbelts on productivity of agronomic crops. The design of the tree belt (strip), the crops being grown adjacent to it, the precipitation that occurs, the type of soil, and many other factors will influence the dynamics of the sheiterbelt and the crops. Use of fast-growing poplar hybrids accelerated the tree-crop interaction.

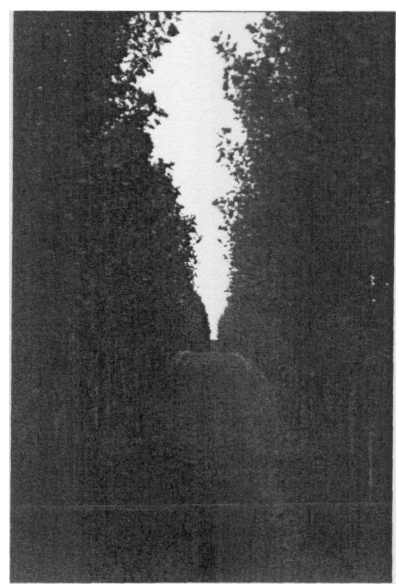
Studies conducted through the shelterbeit development phase allowed assessment of the evolution from a monospecies (crop) ecosystem to a biospecies (crop and tree) agroforestry system. The project objectives were to evaluate the effect of a shelterbeit on crop development and yield as a function of sheiterbelt parameters (height, porosity, etc.), distance from the sheiterbelt, and root pruning, and to collect information on the costs and benefits of the sheiterbelt system.

Approach and methods

In 1992, a sheiterbelt composed of four rows of poplar hybrids was established on the Dennis and Linda Morgan farm near Ogden, Iowa. The poplars were planted with four feet between the trees in each row and 10 feet between rows. The space between the rows was mowed periodically.

Downwind from the sheiterbelt, twelve 50 by 300 foot plots were established, with the 300- foot side perpendicular to the trees. In 1994, the plots were extended 100 feet, making the perpendicular side 400 feet long. Four blocks were sec-

Shelterbelts have been used in cropping systems for more than a century.



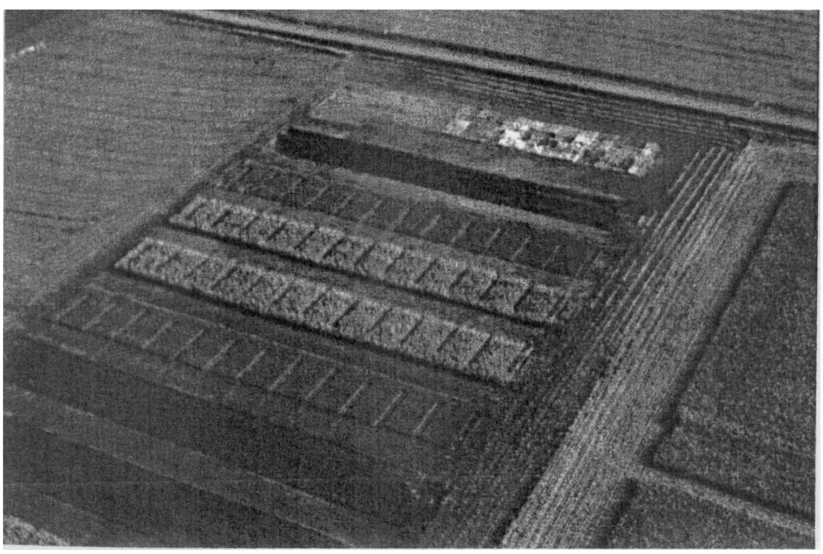
tioned off and within each block, one plot was planted to corn, another to soybeans, and a third to oats. Crops were rotated annually among the plots in each block.

A 8-foot open space was left between the trees and the crops each year. In the middle of the 8-foot space, a subsoiler was used in 1995 to prune the roots of the trees next to the crops in two of the four blocks. A polyethylene sheet was placed in a trench running parallel to the trees and between the trees and crops to intercept tree root growth which might otherwise extend into the plots.

Crops were planted using reduced tillage practices each year. Harvest for crop grain yield was done at selected distances within the shelterbelt, as were measures of the crop development. Neutron probe access tubes were placed in the tree row adjacent to the crop, within the crop row adjacent to the shelterbelt, and 15 feet into the crop plots following the emergence of corn and soybeans. A neutron probe was used to measure soil water content monthly during the growing season until late-stage reproductive growth began in the corn and soybeans.

In late summer 1996, wind speed sensors were installed on a line perpendicular to the shelterbelt extending east (downwind) from the shelter. Sensors were placed at distances of 1H, 3H, and 10H (H equals shelterbelt tree height) from the edge of the shelterbelt. Information from these instruments will be used to determine the effect of the shelterbelt on wind flow.

Aerial view of Morgan farm sheiterbelts.



Results

In the first years of the study, crop yield patterns in the absence of a shelterbelt were identified. Changes in these patterns with distance from the shelterbelt were used to measure shelterbelt effects on crop production.

Near normal growing conditions were experienced throughout most of the project with the exception of 1993. That year's heavy rainfall depressed crop yields and negatively impacted tree growth, especially in the southern portion of the shelterbelt.

Tree heights: Trees grew moderately rapidly, reaching 16 feet in 1995. This produced relatively early shelterbelt impacts on the microclimate as well as on crop growth and yield. Height was considered more critical than other tree growth characteristics. (In 1997, two rows in the shelterbelt will be cut so that new growth will improve flow resistance at lower levels and create different impacts on crops.)

Soil water content: From 1992 to 1994, the time when soil water content was measured was nearly always significant for each crop within a given year. (Precipitation prior to measurement or differences in water use patterns for crops affected the measurements.) No significant differences occurred between the three measured positions for soybean and oats during the three years studied. Corn showed differences only in 1992 when the crop/shelterbelt border position had a lower soil water content than the other positions. This suggests that in the early years of tree establishment in the hybrid poplar shelterbelt, the trees will not compete with the crops for moisture. In the last two years of the project, data indicated that tree root competition for water in the crop plants was not important and the root pruning and plastic barrier treatment had little effect on crop growth and yield.

Plant biomass: As with grain yield, significant differences between years occurred for a few of the crop biomass samplings at particular growth stages. However, in the combined 1992 to 1994 analysis, data for the first three sampled growth stages showed no consistent significant differences among the sampled positions. Plot border effects did not appear to extend beyond the second row for each crop. In 1995 and 1996, biomass was typically reduced in the zone bordering the trees. The shelterbelt did not seem to positively affect biomass accumulation of either crop in the measured locations. Little competition for soil resources seemed evident five years after planting the shelterbelt at this distance from the cropped area.

Yield: Crop grain yields for the first three years displayed few similar trends and no discernible patterns across the plots. Each crop did experience significant differences in grain production between years, which was likely due to the extreme amount of precipitation in 1993. When three years of data were combined in a single analysis for each crop, however, no significant differences existed among sampled positions for grain yield of crops, but a baseline was established for future comparisons.

A corn yield pattern first started to develop in 1995. Yields directly adj acent to the shelterbelt were negatively affected. However, yields starting at about 15 feet from the shelterbelt yielded more than expected. In 1996, similar yield patterns existed. Of primary importance is that the distance over which yield enhancements were observed increased from 1995 to 1996.

Soybean yields were less influenced by the shelterbelt than were corn yields. In both 1995 and 1996, little yield pattern change from that normally expected at this site was observed. Immediately adjacent to the shelterbelt, yield decreases (1995) and increases (1996) were observed. Reasons for the difference were not determined.

Data suggest that corn yield is more likely to respond favorably to shelterbelts than is soybean yield, but caution must be used in comparing corn and soybean responses. The shape of the hybrid poplars is such that an open space exists for the first few feet above the ground in this shelterbelt. This minimizes wind obstruction near the ground. Soybeans are much shorter than corn, and therefore may experience less sheltering effect. Weather station placement in 1996 indicated that at a height of 1 meter, wind speed reduction of at least 13 percent might be expected immediately behind the shelterbelt. Less impact would likely be observed at lower levels.

Conclusions

Prior to establishment of the shelterbelt, the field plot area had no particular yield patterns associated with distance from the shelterbelt. This provided a baseline for making comparisons of shelterbelt effects on crop yield and growth. For three years after shelterbelt establishment, no effects on crop growth and yield were observed.

In the fourth year following establishment, corn yield response to the shelterbelt was observed. Effects were more pronounced in the fifth year. Corn responds to the effect of a hybrid poplar shelter within four to five years after planting (for shelters of similar design, on similar soil, and with similar climatic conditions).

The structure for the hybrid poplar (little wind obstruction near the ground) reduces the likelihood of effects on shorter crops. This is a preliminary conclusion, however, and needs further supporting evidence.

Root pruning and plastic sheet placement to reduce tree root competition within the plot does not seem to affect crop growth, yield, or total soil water content in the soil profile. Impacts may occur at a later time as trees mature.

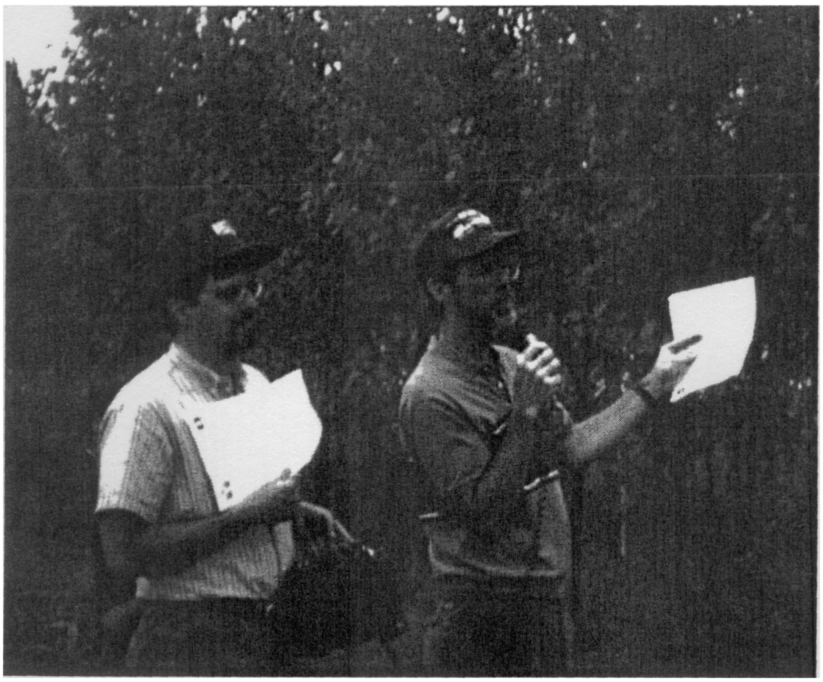
Implications

Results so far have shown only a slight impact of shelterbelts on crop yield. But the project has been a catalyst in the continued develop-

ment of an interdisciplinary research team at Iowa State; University of Nebraska; Agrophysical Institute of St. Petersburg, Russia; and the USDA Forestry Service Rocky Mountain Forest Experiment Station. The team has developed a Shelterbelt Agroforestry Modeling System (SAMS). The system simulates the growth and response of corn and soybeans grown under the influence of a shelterbelt.

SAMS consists of three interconnected models. The first (TREE) estimates the vertical distribution of the combined surface area of the leaves, branches, and stem. The micrometeorological model (MICRO) uses weather conditions in an unsheltered location together with the surface area distribution from TREE

Principal investigator Carl Mize (right) and Center education coordinator Rich Pirog at 1996 shelterbelt field day.



to determine the complete microclimate at all locations for each day of the growing season. The third model (CROPS) predicts crop growth in response to environmental and management conditions. SAMS can also use corn and soybean growth models.

SAMS was used to estimate the yield profile across a field of soybeans grown under the influence of a 10-year-old shelterbelt composed of four rows of hybrid poplar using weather data from central Iowa. The yield profile appears similar to that for other crops grown under shelter.

For more information contact Carl Mize, Forestry, Iowa State University, Ames, Iowa 50011; (515) 294-1456; e-mail cwmize@iastate.edu.

Based on the ability of SAMS to simulate a response to shelter and the growing interest of the research team, a proposal was submitted to the agricultural systems program of the Competitive Grants Program of the National Research Initiative (NRI) in early 1996. The proposal—Modeling a Shelterbelt Agroforestry System—used modeling to design shelterbelts for optimizing corn and soybean production in the Midwest.

In late 1996, the NRI funded the project at $330,000 for three years to develop a characterization of shelterbelts that will allow the new microclimatic model to be incorporated in SAMS. Funding from the Leopold Center has been critical in encouraging the progress of the group of researchers involved in the development of SAMS.

Education and outreach

In 1993, the Third North American Agroforestry Conference sponsored a field trip to the shelterbelt site. Nearly 200 people from the United States and abroad heard the ISU researchers describe various aspects of the project. The shelterbelt project was the topic of a 1994 soils seminar in the ISU Agronomy Department.

A shelterbelt tour field day was held July 11, 1996 under the sponsorship of the Leopold Center and the ISU Department of Forestry. About 25 people were present to view the shelterbelt and the three test crops and hear how and why to establish a shelterbelt. Those who responded to tour evaluation said that they gained a better understanding of what shelterbelts can do.

The Morgans, owners of the farm where the shelterbelt is located, have kept 100 to 150 people in their area informed about the shelterbelt and the ongoing study. Some of the Morgans' neighbors have indicated interest in establishing a shelterbelt on their land.